

Summary of Research

NASA-Ames Cooperative Agreement Number NCC 2-939

**Investigation of the Physical Processes Governing Large-Scale
Tracer Transport in the Stratosphere and Troposphere**

For the period January 1, 1996 through May 31, 1999

Submitted to

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Accomplishments

This report summarizes work conducted from January 1996 through April 1999 on a program of research to investigate the physical mechanisms that underlie the transport of trace constituents in the stratosphere-troposphere system. The primary scientific goal of the research has been to identify the processes which transport air masses within the lower stratosphere, particularly between the tropics and middle latitudes. This research was conducted in collaboration with the Subsonic Assessment (SASS) of the NASA Atmospheric Effects of Radiation Program (AEAP) and the Upper Atmospheric Research Program (UARP). The SASS program sought to understand the impact of the present and future fleets of conventional jet traffic on the upper troposphere and lower stratosphere, while complementary airborne observations under UARP seek to understand the complex interactions of dynamical and chemical processes that affect the ozone layer. The present investigation contributed to the goals of each of these by diagnosing the history of air parcels intercepted by NASA research aircraft in UARP and AEAP campaigns. This was done by means of a blend of trajectory analyses and tracer correlation techniques.

A primary tool employed in the research has been isentropic trajectory analysis. This tool has been applied in a number of ways. In collaboration with Dr. Leonhard Pfister of NASA Ames Research Center applications of trajectory analysis have been developed that can be used to diagnose the interaction of air parcels with deep convective cloud processes and aircraft emissions. The former technique, called "convective influence", was first used in 1997 in support of flight planning for the SASS Ozone and Nitrogen Oxide Experiment (SONEX) and has since been used in the field campaign Atmospheric Chemistry of Combustion Emissions Near the Tropopause (ACCENT), also sponsored in part by SASS. The second technique was in development at the end of the research period.

At the joint meeting in June 1998 of the science teams of the NASA airborne missions Stratospheric Tracers of Atmospheric Transport (STRAT) and Polar Ozone Loss in Arctic Regions in Summer (POLARIS), Dr. Selkirk presented results from trajectory-based investigations of the origins of air parcels observed by the NASA ER-2 aircraft during tropical flights over the 1994 through 1996 period. A key finding was that there were clear differences between seasons in the degree of ingress of parcels from the middle latitude stratosphere into the lower tropical stratosphere.

During 1998, Dr. Selkirk's principal research focus was a series of investigations from the Subsonic Assessment Ozone and Nitrogen Oxides Experiment (SONEX). The SONEX field mission took place in the fall of 1997, during which the NASA DC-8 aircraft flew a number of missions out of Shannon, Ireland, the Azores and Bangor, Maine. Data from four flights have been examined closely for the role of deep convective disturbances and lightning on the levels of nitrogen oxides. The approach used combines back trajectory analysis with large-scale grids of infrared brightness temperatures derived from

geostationary satellite measurements. The technique yields a measure of the likelihood that individual air parcels have been in contact with convective outflows and consequently the potential for enrichment with chemical by-products of lightning and surface air chemistry. Cloud-to-ground lightning flash rates observed by the National Lightning Detection Network have also been used in this work and have been used in the trajectory analysis. While data from two of the flights over North America show strong enrichment with nitric oxide and overall height levels of total reactive nitrogen that are consistent with observations of convection and lightning events just hours before sampling, similar enrichments were observed over the mid-Atlantic that were traced back by the convective influence technique to convective events over Florida one to two days earlier. Dr. Selkirk reported on these investigations at the first SONEX post-mission science meeting at Georgia Tech in June, 1998. The work has subsequently been expanded to include a comparison of the kinematic trajectory technique with the isentropic analysis technique in the context of the convective influence technique. The results from this study will be reported later in 1999 in the SONEX special section of the Journal of Geophysical Research.

Meteorological support of field missions was an integral part of the research done under the Cooperative Agreement. During 1996, Dr. Selkirk provided meteorological and scientific support to both VOTE (the Vortex Ozone Transport Experiment) in January and February and three campaigns of the STRAT mission. The first of STRAT campaigns took place concurrently with that of VOTE, while the other two took place in the July-August period and in December. During VOTE, Dr. Selkirk provided flight planning support to Missions Scientists Drs. Mark Schoeberl and Brian Toon. In this capacity he provided meteorological guidance to the science team and managed the transfer of data products used in the flight planning process to the field sites in Alaska, Iceland and Hawaii. Flight planning support was also provided to the Observations of the Middle Stratosphere (OMS) balloon campaign in September during which the ER-2 was deployed from NASA Ames to intercept the balloon's descent profile over eastern New Mexico.

Dr. Selkirk provided meteorological and scientific support to the Polar Ozone Loss in the Arctic Regions in Summer (POLARIS) in 1997. The goal of this mission was to better characterize and quantify the ozone losses that occur during the Arctic summer. For this purpose, the NASA ER-2 aircraft was flown from Fairbanks, Alaska in three separate deployments between April and September 1997. Dr. Selkirk provided meteorological support in Fairbanks during the first two of these missions.

As Co-Investigator with Dr. Anne Thompson of NASA-Goddard, Dr. Selkirk provided meteorological and scientific support to the SASS Ozone and Nitrogen Oxide Experiment in 1997. This entailed 24 days in the field in October and November as well as participation in planning meetings at Ames and Goddard in February and June, respectively. During the nine months leading up to the field mission, Dr. Selkirk devoted much of his time to preparations for the field mission, and in particular played the lead role in developing the rather complicated flight plans required to satisfy the scientific goals of SONEX. Once in

the field, in addition to his role in retrieving and interpreting scientific forecast products specifically designed for the mission by him and his colleagues at Ames and Goddard, Dr. Selkirk assisted the Mission Scientists in preparing the final details of the flight plans .

Publications

Jensen, E. J., O. B. Toon, H. B. Selkirk, J. D. Spinhirne, and M. R. Schoeberl, On the formation and persistence of subvisible cirrus clouds near the tropical tropopause, *J. Geophys. Res.*, **101**, 21 361, 1996.

Jensen, E. J., O. B. Toon, L. Pfister and H. B. Selkirk, Dehydration of the upper troposphere and lower stratosphere by subvisible cirrus clouds near the tropical tropopause, *Geophys. Res. Letts.*, **23**, 825, 1996.

Meeting presentations

"Seasonal variation of the tropical pipe." Oral presentation at the Spring Meeting of the American Geophysical Union in Baltimore, Maryland, May 20-23, 1996.

"Vertical structure and origin of subtropical tropopause layers at Hawaii: Observations and trajectory calculations from ASHOE-MAESA and STRAT." Poster presentation at the annual meeting of the Atmospheric Effects of Aviation Program, Virginia Beach, VA, April 1997.

"Subvisible cirrus clouds near the tropical tropopause." Co-author with L. Pfister. Oral presentation by Pfister at the SPARC Meeting on Mesoscale Processes in the Stratosphere, Bad Toelz, Germany, 9-11 November, 1998.

APPENDIX

Subject Inventions Certification

There were no subject inventions required to be disclosed to NASA which resulted from this work. There were no subcontracts awarded under this Cooperative Agreement.